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Document Title **CAL Flight Module (FM 106 - FM 111) Vibration Test Report**		

Gamma-ray Large Area Space Telescope (GLAST)

Large Area Telescope (LAT)

Calorimeter Flight Module (FM 106 - FM 111) Vibration Test Report

MASTER DOCUMENT
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DOCUMENT APPROVAL

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CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
01	3 January 2004	Initial Release

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1 INTRODUCTION

1.1 PURPOSE

This report presents the results of the acceptance structural environment test performed on several GLAST Calorimeter (CAL) Modules, designated as Flight Module 106 (FM 106) through Flight Module 111 (FM 111). These tests were performed between November 22, 2004 and January 27, 2005 in accordance with LAT-PS-04454-03, *CAL Flight Module Vibration Test Procedure*, and the following work orders:

WORK ORDER NUMBER	WORK ORDER TITLE
WOA-01620	Vibration Test for FM 106
WOA-01621	Vibration Test for FM 107
WOA-01622	Vibration Test for FM 108
WOA-01684	Vibration Test for FM 109
WOA-01685	Vibration Test for FM 110
WOA-01686	Vibration Test for FM 111

1.2 OBJECTIVE

The objective of this test was to verify the design and workmanship of several GLAST CAL Flight Modules, FM 106 through FM 111, in accordance with the Large Area Telescope (LAT) Program Instrument Performance Verification Plan, LAT-MD-00408. The design and workmanship was verified by subjecting these modules to an acceptance test program, which subjected the CAL Module to test levels that exceeded the maximum expected launch and ascent dynamic environments. The fundamental frequency of each CAL Module was verified by subjecting it to low-level random vibration. The environments were simulated by random vibration and sine-sweep.

1.3 OVERVIEW

Structural environment testing was conducted at the Vibration Test Laboratory of the Payload Check-Out Facility (Building A-59) at the Naval Research Laboratory, Washington, D.C. Testing consisted of the standard NRL-approved technique of attaching the test article to either a slip table (transverse axes tests) or head expander (vertical axis tests) and conducting a series of prescribed vibration tests of various levels and types.

All Flight Modules were successfully subjected to acceptance level structural environments. Response limits were adjusted to ensure that the test article was not over-tested and met the minimum predicted environments.

The fundamental frequency was characterized before and after subjecting each CAL Module to the acceptance level structural environments. Negligible differences were seen between the pre- and post-test signatures.

Following environmental testing, comprehensive electrical performance testing and muon collection were conducted. No anomalies were noted. In addition, the structure underwent a thorough visual inspection. Again, no anomalies were noted.

Therefore, FM 106 through FM 111 have successfully passed the CAL Flight Module Vibration Test in accordance with in accordance with LAT-PS-04454-03, and thus, are considered acceptable for flight.

2 APPLICABLE SPECIFICATIONS

Documents required to perform this test include the as-run version of LAT-PS-04454, *CAL Flight Module Vibration Test Procedure*, and the associated work order (WOA). The applicable documents cited in this standard are listed in this section for reference only.

2.1 GOVERNMENT SPECIFICATIONS

Number	Title
GEVS-SE	General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components

2.2 NON-GOVERNMENT SPECIFICATIONS

Number	Title
LAT-MD-00408	LAT Program Instrument Performance Verification Plan
LAT-MD-01370	CAL Comprehensive and Limited Performance Test Definition
LAT-MD-04187	CAL Electronic and Muon Calibration Definition
LAT-PS-01513	CAL Functional Test and Calibration Procedure
LAT-PS-04237	CAL Module Handling Procedure
LAT-PS-04454	CAL Flight Module Vibration Test Procedure
LAT-SS-00788	LAT Environmental Specification
LAT-SS-01345	CAL Module Verification & Environmental Test Plan
LAT-TD-01888	CAL Module – Engineering Module (EM) Vibration Test Report
LAT-TD-05138	CAL Flight Module 101 Vibration Test Report
SAI-TM-2378	Pre-Test Analysis Report for CAL EM3 Module (11 Feb 2003)
N/A	Instrumentation Manuals

2.3 DRAWINGS

Number	Title
LAT-DS-00916	Calorimeter Module, GLAST
LAT-DS-01643	TEM-TPS Assembly, GLAST
LAT-DS-04536	Tower Module, Calorimeter, GLAST

2.4 ORDER OF PREFERENCE

In the event of a conflict between this document and the technical guidelines cited in other documents referenced herein, the technical guidelines of this document take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3 TEST DECRIPTION

3.1 TEST OBJECTIVE

The objective of this test was to verify the design and workmanship of each GLAST CAL Module (FM 106 through FM 111) by determining the fundamental frequency and subjecting it to acceptance test levels that exceed the maximum expected launch and ascent dynamic environments.

3.2 TEST METHODOLOGY

The structural environmental test was divided into three tests, which were performed on each of the three axes of the acceptance unit: the transverse axes (X and Y) and the thrust axis (Z).

The three tests that comprise the structural environmental test are:

- Frequency Survey – Each test article was subjected to a low-level random vibration environment to define a pre-test and post-test signature of the test article.
- Random Vibration Test – Each test article was subjected to the dynamic environment defined by the acceptance random vibration acceleration spectral density.
- Sine-Sweep Test (Sinusoidal Vibration Test) - Each test article was subjected to the dynamic environment defined by the acceptance sine-sweep spectrum.

The fundamental frequency of each test article was verified by evaluating the frequency response function measured while subjecting the test article to a low-level random vibration environment. This activity defined the pre-test signature of the test article prior to subjecting it to the test environments. Accelerometer data was reviewed following the test to determine locations with high response.

The next test in the test flow was the random vibration test. The test subjected the test article to –12 dB of the full random vibration level and continued onto full level once the response at the lower level was confirmed.

Following the random vibration test, the test article was subjected to a sine-sweep test.

A final low-level random vibration, which was run following the sine-burst test, defined the post-test low-level signature of the test article. Comparison of the frequency response functions before and after this test was used to determine that no structural change occurred to the test article.

Following structural environmental testing, a comprehensive performance test (CPT) of the AFEE and TEM electronics was performed in accordance with LAT-PS-01513, *CAL Functional Test and Calibration Procedure*. This test established that proper communication between TEM and CAL still exists, that all registers of the CAL function properly, that pedestal amplitude and noise in all four energy ranges remain stable, and that the optical performance of each CDE remains stable. These results were then compared to the reference CPT, which was conducted prior to entry of the CAL Tower Module into the environmental test program.

3.3 TEST ARTICLE DESCRIPTION

The test articles are the GLAST CAL Tower Modules, FM 106 through FM 111, as documented in the as-built configuration list (ABCL) shown in Table 5.1.

Each CAL Tower Module (LAT-DS-04536) consists of the CAL Module (LAT-DS-00916) with the Tower Electronics Module/Power Supply (TEM/TPS) Assembly (LAT-DS-01643) attached to the CAL Module base plate by means of four rigid stand-offs. The total weight of each unit is approximately 206 lbs.

There were no deviations from the flight configuration with the exception of:

- Electrical Harness from the TPS was removed.
- The TEM/TPS Assembly is version EM2, rather than Flight.

The GLAST CAL Module in flight configuration is shown in Figure 3-1.

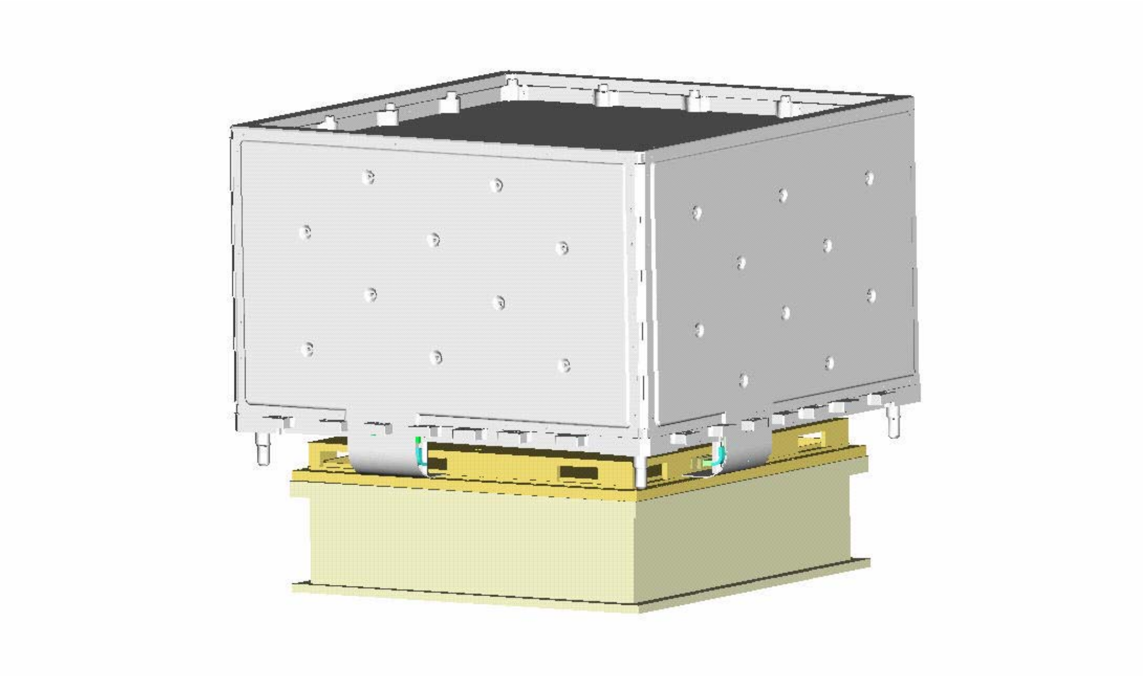


Figure 3-1: CAL FM in Flight Configuration with TEM/TPS

4 TEST RESPONSIBILITIES

4.1 TEST PERSONNEL

The following personnel, as listed in Table 4-1, participated in the vibration test

Table 4-1: Test Personnel

Role	Name	Telephone Number
Project Representative	Eric Grove	202-767-3112
Test Director	Paul Dizon	202-404-7193
Test Conductor, Primary	Bob Haynes	202-767-0705
Test Conductor, Electrical Subsystem	Byron Leas	202-404-1464
Test Conductor, Science Subsystem	Eric Grove	202-767-3112
Instrumentation/Data Support	Jim Layher	202-767-0705
Analysis Support	Jon Shaw	301-902-4260
	Jim Haughton	202-767-4689
	Chuck Williams	202-767-6696
Quality Assurance Support	Nick Virmani	202-767-3455
	James Lee	202-404-1476
	Lamont Franklin	202-404-1332

5 GENERAL TEST PROGRAM REQUIREMENTS

5.1 TEST SETUP

5.1.1 Test Location

The structural environmental tests were conducted in the Vibration Test Laboratory of the Payload Check-Out Facility, Building A-59, at the Naval Research Laboratory, Washington, D.C.

5.1.2 Test Article Configuration

Each CAL Tower Module was mounted in the upright position onto a two-piece vibration test fixture. The two-piece test fixture consists of a CAL base plate adapter and the primary fixture, which mounts directly to the slip table of the vibration table. The As-Built Configuration Lists (ABCL) of the CAL Tower Modules in their test configurations are shown in Table 5-1 through Table 5-6.

Table 5-1: As-Built Configuration List – Vibration Test of FM 106

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 106	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 106	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM07	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

Table 5-2: As-Built Configuration List – Vibration Test of FM 107

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 107	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 107	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM10	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

Table 5-3: As-Built Configuration List – Vibration Test of FM 108

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 108	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 108	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM11	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

Table 5-4: As-Built Configuration List – Vibration Test of FM 109

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 109	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 109	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM05	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

Table 5-5: As-Built Configuration List – Vibration Test of FM 110

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 110	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 110	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM08/FM1	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

Table 5-6: As-Built Configuration List – Vibration Test of FM 111

Assembly / Component	Part Number	Status
Calorimeter Tower Module, s/n FM 111	LAT-DS-04536	Flight/GSE
Calorimeter Module, s/n FM 111	LAT-DS-00916	Flight
TEM/TPS Assembly, s/n FM13/FM2	LAT-DS-01643	GSE
M6 Screws, Socket-Head Cap (QTY 4)	NA0069-060024	GSE
M6 Washers, Flat (QTY 4)	A370-903-32	GSE

5.1.3 Test Equipment

The following test equipment and systems were used in the execution of the tests:

- Test Article: CAL Module Tower Module (FM 106 through FM 111)
  (CAL Module, EM-2 TEM-TPS electronics box)
- Test Article Support: CAL Vibration Test Fixture (LAT-DS-01314)
  CAL Vibration Test Fixture Interface Plates (LAT-DS-01518, LAT-DS-01519)
  CAL Lift Fixture Assembly (LAT-DS-04138)
- Accelerometers: 3 Endevco Model Piezoelectric Tri-Axial Accelerometers
  4 Endevco Model Piezoelectric Uni-Axial Accelerometers
- Charge Amplifiers: Endevco Model 2775A Charge Amplifiers
  Unholtz Dickie Model D22 Charge Amplifiers
- Vibration Test System: Ling Electronics Electrodynamic Shaker
  GenRad Model 2550 Vibration Control System
  Ling Model 8096B Power Amplifier
  Ling Model SSW-1340-230s Switching Unit
  Unholtz-Dickie Model T-5000 Electrodynamic Shaker
  Unholtz-Dickie Power Amplifier
- Data Acquisition System: Hewlett Packard VXI Data Analysis System
- CAL Electrical Ground Test Equipment

The test fixture, as shown in Figure 5-1, supported each CAL Tower Module in the upright position. Since the CAL Tower Module must be removed from the test fixture each time the assembly is re-oriented for each axis test, the CAL Tower Module was attached to the test fixture via a bolt-on interface plate assembly, as shown in Figure 5-2. This assembly was attached to the tabs of the CAL Module base plate via 56 fasteners. Because these fasteners are inaccessible within the test fixture due to the mounting design of the CAL Module, the bolt-on feature of the interface plate facilitated the re-orientation process. After the interface plate assembly was installed onto the base plate of the CAL Module, the shear pins were secured via shear plates, as shown in Figure 5-3.

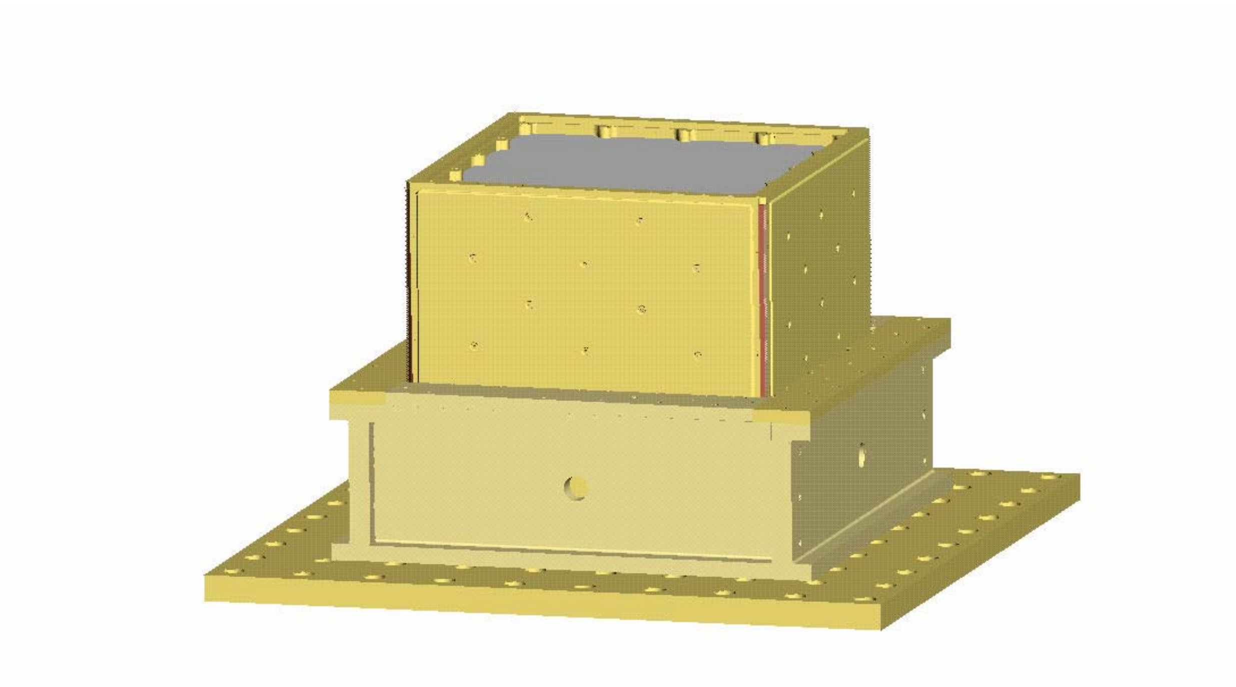


Figure 5-1: Test Fixture with FM CAL Module

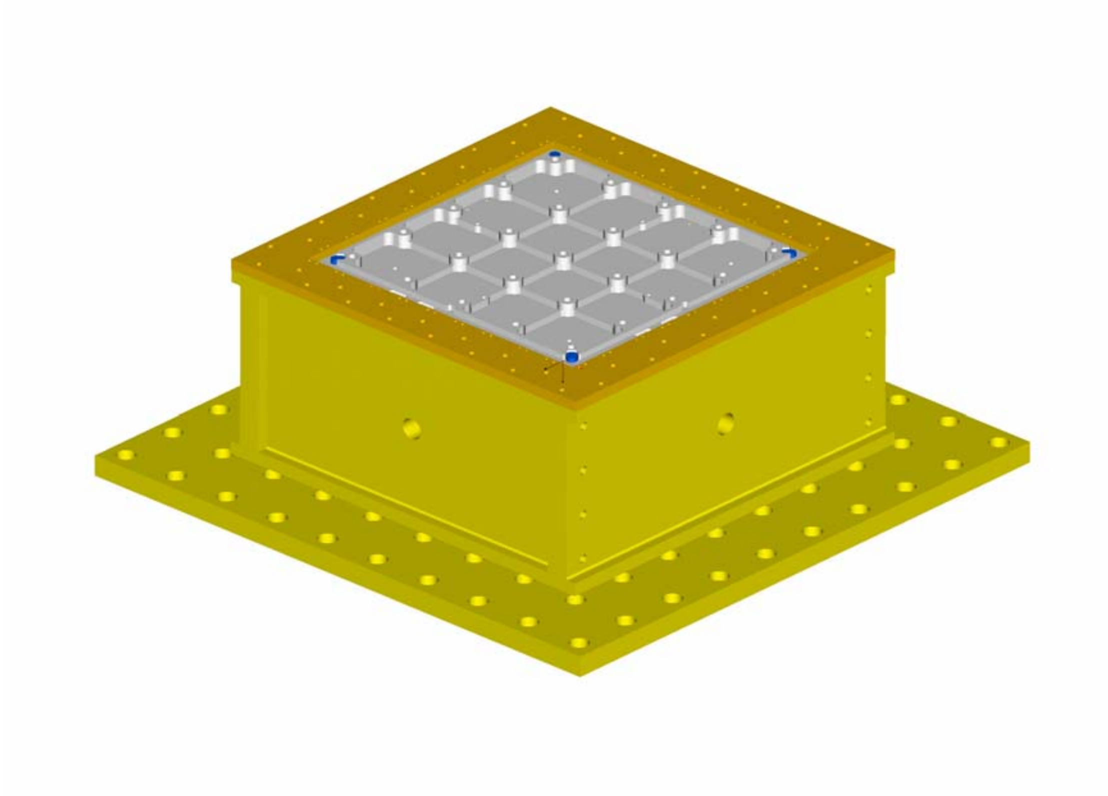


Figure 5-2: Test Fixture Showing Interface Plates

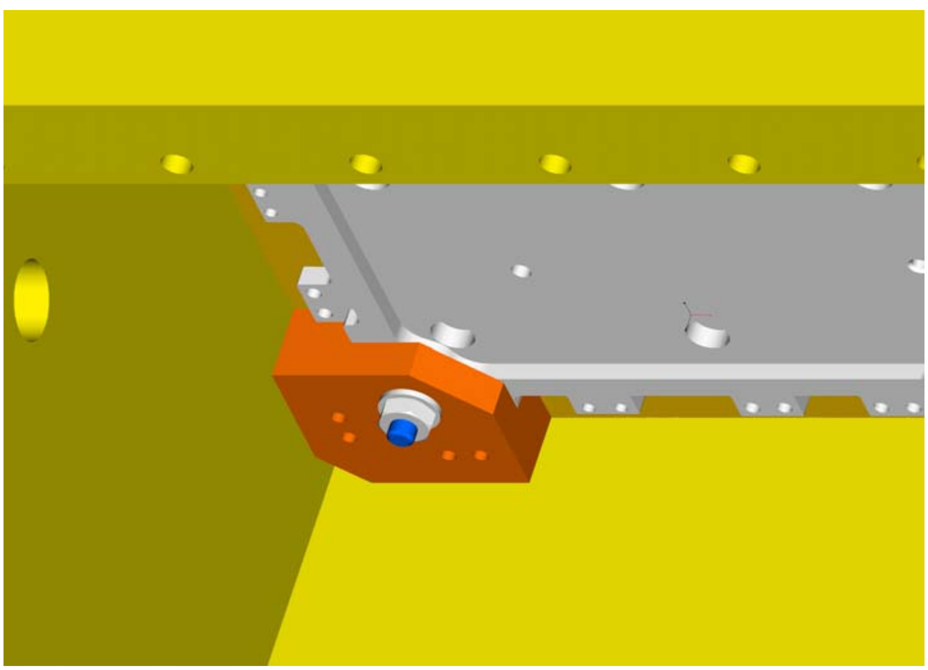


Figure 5-3: Test Fixture Showing Shear Plate Interface

5.2 INSTRUMENTATION AND DATA ACQUISITION

5.2.1 Instrumentation

Two calibrated tri-axial accelerometers were used to measure the response acceleration of each test article. These accelerometers were attached at points of interest or at points expected to have high response acceleration where response limiting was expected. Furthermore, one calibrated tri-axial accelerometer was attached at the corner of the CAL Tower Module-test fixture. Two pairs of uni-axial accelerometers were attached to the interface plane (one pair) and the base plate (one pair) of the test fixture for shaker control.

Table 5-2 lists the accelerometers used in this test. All accelerometers were aligned with the CAL coordinate system shown in Figure 3-1. Accelerometer locations are illustrated in Figure 5-4.

One of these accelerometer channels was monitored during random vibration testing of the CAL in order to response limit components with known limitations so that random vibration levels did not exceed EM component test levels.

5.2.2 Calibration

NRL standard vibration laboratory calibration techniques were used to calibrate all test equipment. All accelerometers were calibrated by comparison against a "Standard Accelerometer" traceable to the National Institute of Standards and Technology and verified by QA.

5.2.3 Data Acquisition

All data was acquired through the VXI Data Acquisition System. The data is stored on the HP VXI computer in digital format with a sampling rate appropriate for a 2000 Hz minimum bandwidth.

5.2.4 Data Reduction

Time history data was stored and analyzed on the HP VXI using SDRC/IDEAS test software. Frequency response functions were generated and stored. All data was analyzed over the 10 to 2000 Hz frequency range. In addition, response power spectral densities and cumulative G_{rms} and Force RMS plots for each channel were generated to monitor the response levels during testing. These data plots contain test description, test date, and name and channel number.

Table 5-7: Accelerometer Locations

Accelerometer ID	Channel ID	Location	Degree of Freedom
1	01X 01Y 01Z	+Z Structure	X Y Z
2	02X 02Y 02Z	Aft Surface of SIU Mass Simulator	X Y Z
3	03X 03Y 03Z	Interface Plate	X Y Z
4	4X, 4Y, or 4Z	Vibration Fixture (Control) - Top Corner	X, Y, or Z
5	5X, 5Y, or 5Z	Vibration Fixture (Control) - Top Corner	X, Y, or Z
6	6X, 6Y, or 6Z	Vibration Fixture (Control) - Plate	X, Y, or Z
7	7X, 7Y, or 7Z	Vibration Fixture (Control) - Plate	X, Y, or Z

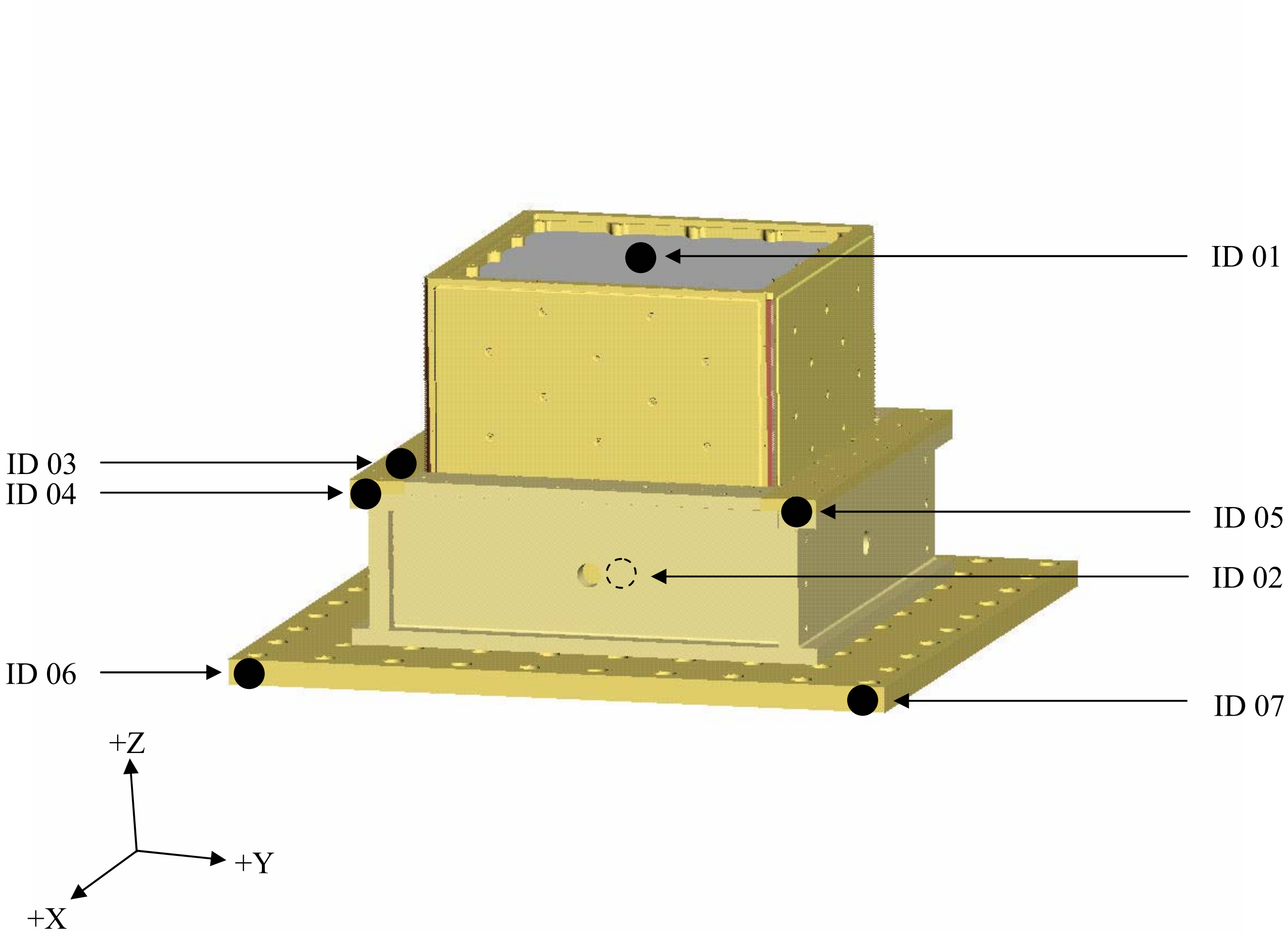
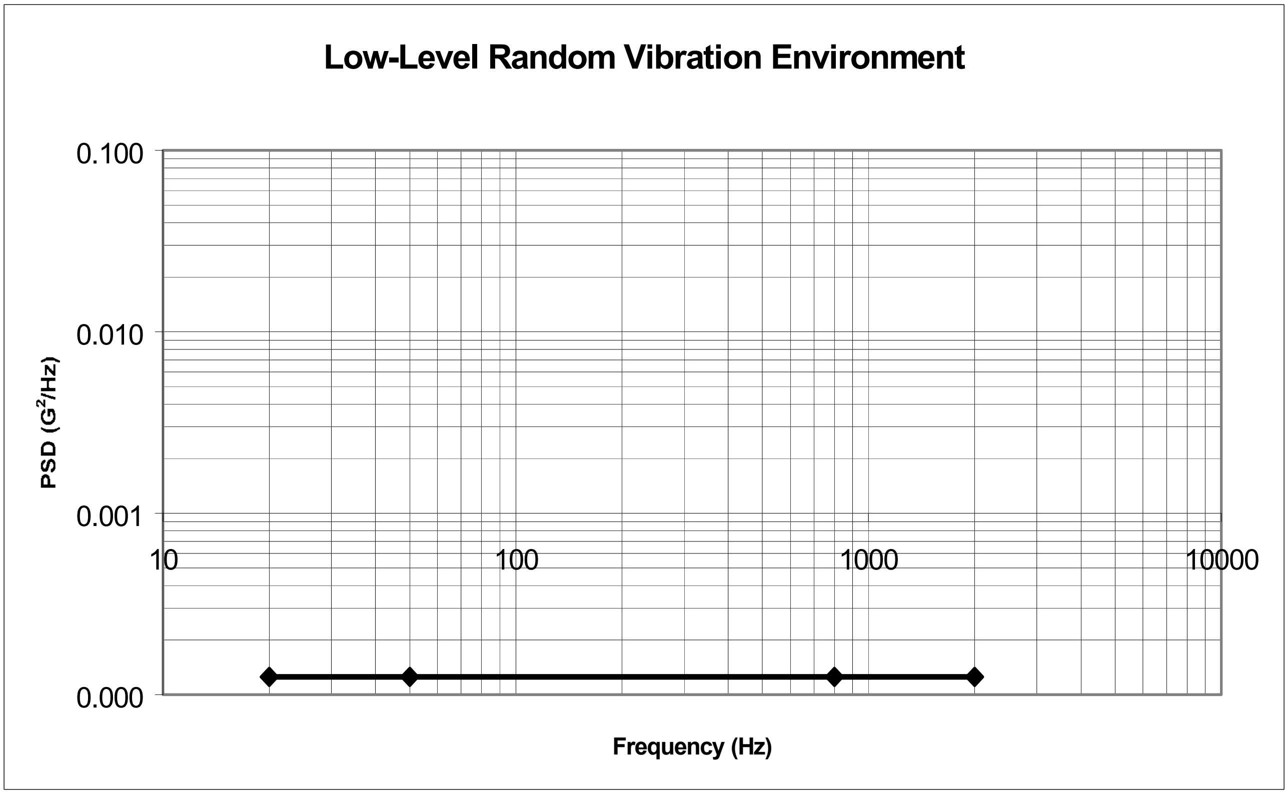


Figure 5-4: Accelerometer Locations

6 TEST LEVELS

6.1 LOW-LEVEL RANDOM VIBRATION FOR FREQUENCY SURVEY

Each axis of the CAL Tower Modules was independently subjected to low-level random vibration for frequency identification and system characterization before and after the test activities. Figure 6-1 contains the low-level random vibration spectrum that was used.



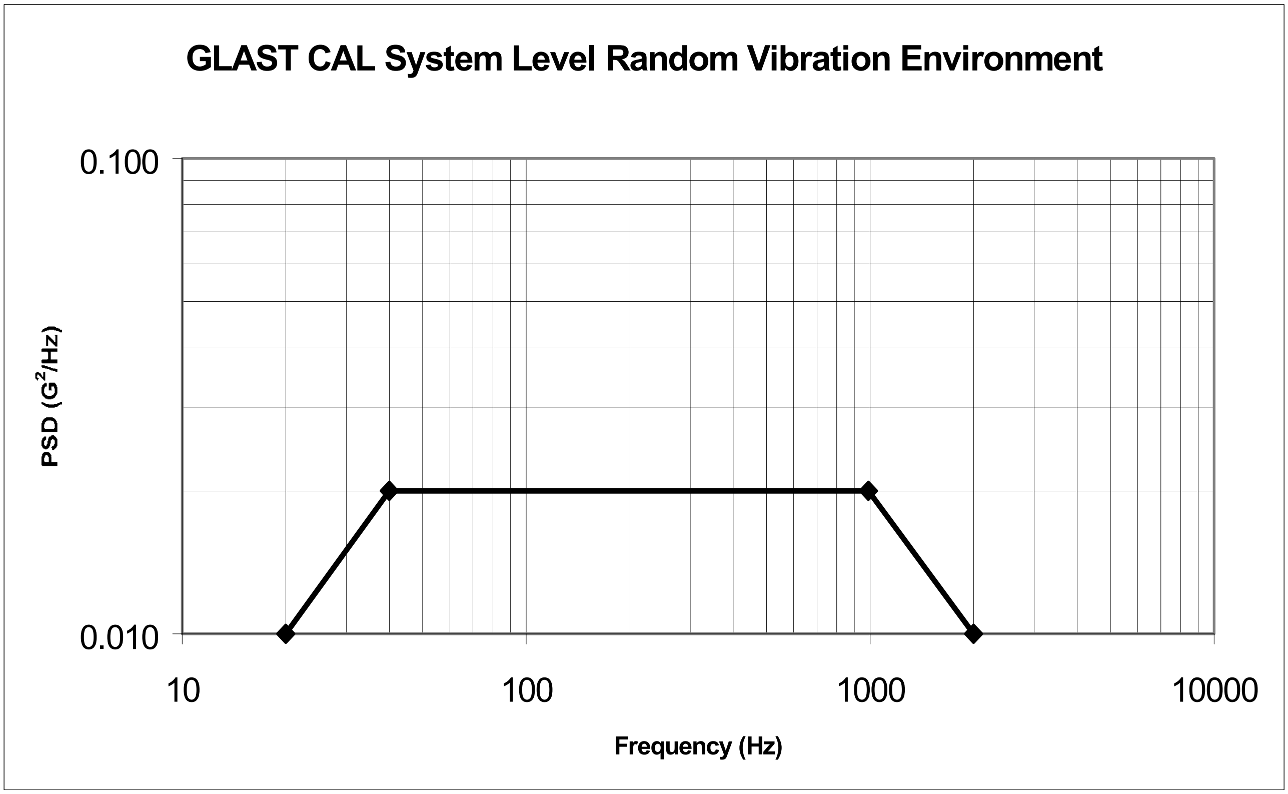
0.5 gRMS	
Frequency (Hz)	g^2/Hz
20	0.000125
50	0.000125
800	0.000125
2000	0.000125

Levels Apply to all Horizontal and Vertical Axes

Figure 6-1: Low-Level Random Vibration Environment

6.2 RANDOM VIBRATION TEST LEVEL

Each axis of the CAL Tower Modules was independently subjected to the random vibration environment shown in Figure 6-2, which is specified in Table 25 of the LAT Environmental Specification, LAT-SS-00778. The structure was subjected to –12 dB random vibration levels before proceeding to the full-level random vibration environment.



Acceptance Levels 5.8 gRMS	
Frequency (Hz)	g^2/Hz
20	0.010
40	0.020
990	0.020
2000	0.010

Test Duration: 1 minute per axis

Levels Apply to all 3 Axes

Figure 6-2: GLAST CAL System Level Random Vibration Environment

6.3 SINE-SWEEP TEST LEVEL

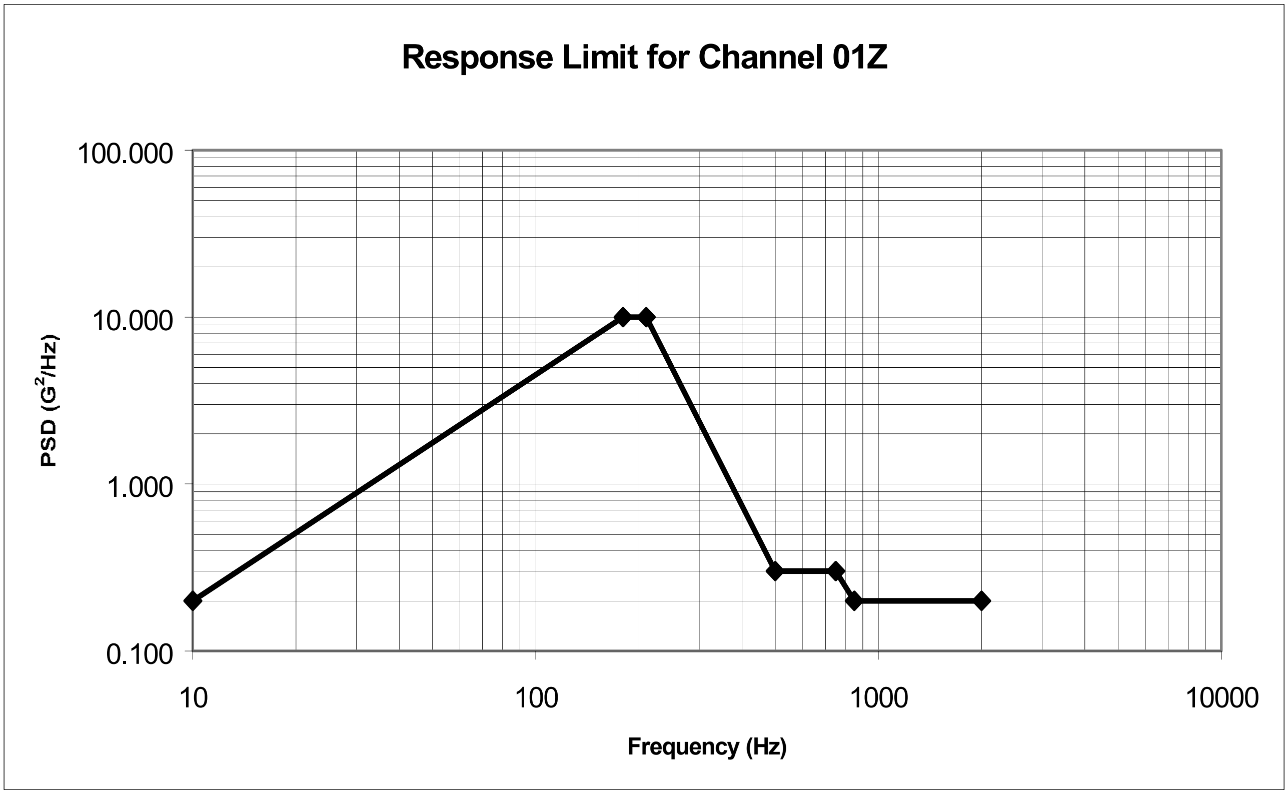
Each axis of the CAL Tower Modules was independently subjected to the sine-sweep environment shown in Table 6-1, which is specified in Table 21 of the LAT Environmental Specification, LAT-SS-00778.

Table 6-1: GLAST CAL System Level Sine-Sweep Test Level

LAT CAL Acceptance Test Levels			
Axis	**Freq. (Hz)**	**Test levels**	**Sweep Rate [Oct/min]**
Thrust (Z)	5 - 20	2 g	4
	25 - 35	4.72 g	4
	40 - 50	1.68 g	4
Lateral (X&Y)	5 - 15	2.16 g	4
	15 - 25	0.96 g	4
	25 - 35	0.96 g	4
	35 - 43	1.2 g	4
	43 - 50	1.52 g	4

6.4 LIMITING ACCELERATIONS

The notching criteria used for this test was based on test results from the CAL Module qualification vibration test (LAT-TD-05128). Responses were limited to prevent them from exceeding the responses observed during the EM CAL Module test. Levels were automatically controlled using response limiting. Accelerations at the interface were also controlled to prevent amplification due to the test fixture.



Frequency (Hz)	g^2/Hz
10	0.200
180	10.000
210	10.000
500	0.300
750	0.300
850	0.200
2000	0.200

Figure 6-3: Response Limit for Channel 01Z

7 TEST SEQUENCE AND RESULTS

7.1 TEST SEQUENCE OF THE TEST FIXTURE

The strength of the test fixture was confirmed and its dynamic behavior was characterized in order to certify control accelerometer locations and verify the pre-test analytical predictions. Testing of the test fixture began on April 22, 2003 (prior to EM CAL vibration test). Results of this test are found in LAT-TD-01888, CAL Module, EM Vibration Test Report.

7.2 TEST SEQUENCE OF THE TEST ARTICLE

Each axis of each CAL Tower Module was independently tested. The test sequence for each axis of each module is summarized in Table 7-1. Test dates are summarized in Table 7-2.

Table 7-1: Test Sequence for each Test Axis

(X-, Y-, and Z-Axes are tested independently)				
	Test Description	**Test Level**	**Duration**	**Comment**
1	Low-Level Random Vibration (Pre-Test Signature)	See Section 6.1	As Required for Data	Identify modal frequency
2	Random Vibration (-12 dB through Full Level)	See Section 6.2 & 6.4	1 Minute (minimum)	Notching Required for Z-Axis Test
3	Sine-Sweep (Full Level)	See Section 6.3		
4	Low-Level Random Vibration (Post-Test Signature)	See Section 6.1	As Required for Data	Compare Pre and Post FRFs

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Table 7-2: Test Dates for each CAL Module

CAL MODULE	TEST DATE
FM 106	November 22, 2004
FM 107	November 23, 2004
FM 108	December 1, 2004
FM 109	January 3, 2005
FM 110	January 6, 2005
FM 111	January 27, 2005

7.3 TEST RESULTS

Plotted data of the input and frequency response of each test sequence for each axis is archived and available at NRL.

7.3.1 X-Axis Test Phase

The fundamental frequency and frequency signature of all test articles were characterized during low-level random vibration (0.5 gRMS, 20-2000 Hz) runs. Low-level random vibration was applied to each test article along the X-axis, as specified in Figure 6.1. The first fundamental frequency of each test article was identified and is summarized in Table 7.3.

Random Vibration test levels were applied along the X-axis at –12 dB and increased to full level, 20-2000 Hz, as specified in Figure 6.2. Full-level testing occurred without a problem.

Sine-sweep test levels were applied along the X-axis at full level, 8-50 Hz. The starting frequency of 5 Hz, as specified in Table 6-1, was updated to 8 Hz because the stroke necessary to drive the test article at 5 Hz exceeded the stroke limitation of the shaker. Full-level testing occurred without a problem.

The pre-test and post-test frequency signatures for the X-axis were superimposed and plotted against each other. Although minimal amplitude changes between the pre- and post-test signatures were noted, there were no significant frequency changes between these two signatures and all shifts were within the prescribed 10% limit.

7.3.2 Y-Axis Test Phase

The fundamental frequency and frequency signature of all test articles were characterized during low-level random vibration (0.5 gRMS, 20-2000 Hz) runs. Low-level random vibration was applied to each test article along the Y-axis, as specified in Figure 6.1. The first fundamental frequency of each test article was identified and is summarized in Table 7.3.

Random Vibration test levels were applied along the Y-axis at –12 dB and increased to full level, 20-2000 Hz, as specified in Figure 6.2. Full-level testing occurred without a problem.

Sine-sweep test levels were applied along the Y-axis at full level, 8-50 Hz. As with the X-axis test, the starting frequency was updated to 8 Hz due to the stroke limitation of the shaker. Full-level testing occurred without a problem.

The pre-test and post-test frequency signatures for the Y-axis were superimposed and plotted against each other. Although minimal amplitude changes between the pre- and post-test signatures were noted, there were no significant frequency changes between these two signatures and all shifts were within the prescribed 10% limit.

7.3.3 Z-Axis Test Phase

The fundamental frequency and frequency signature of all test articles were characterized during low-level random vibration (0.5 gRMS, 20-2000 Hz) runs. Low-level random vibration was applied to each test article along the Z-axis, as specified in Figure 6.1. The first fundamental frequency of each test article was identified and is summarized in Table 7.3.

Random Vibration test levels were applied along the Z-axis at –12 dB and increased to full level, 20-2000 Hz, as specified in Figure 6.2. Response limits, as defined from results of the FM CAL Module qualification vibration test documented in LAT-TD-05128, were applied. Full-level testing occurred without a problem with automatic limits occurring in the high frequency range (1600 Hz-2000 Hz).

Sine-sweep test levels were applied along the Z-axis at –full level, 8-50 Hz. As with the previous test axes, the starting frequency was also updated to 8 Hz due to the stroke limitation of the shaker. Full-level testing occurred without a problem.

The pre-test and post-test frequency signatures for the Z-axis were superimposed and plotted against each other. Although minimal amplitude changes between the pre- and post-test signatures were noted, there were no significant frequency changes between these two signatures and all shifts were within the prescribed 10% limit.

7.3.4 Comprehensive Functional Testing

Following vibration test sequence for all axes, each CAL Tower Module was installed into the shipping container for transportation to the functional test area.

Each CAL Tower Module underwent comprehensive functional performance testing as well as cosmic muon collection, in accordance with LAT-PS-01513, CAL Functional Test and Calibration Procedure, to verify the function of the AFEE and TEM electronics.

FM 106 through FM 111 successfully completed comprehensive functional performance testing and cosmic muon collection.

7.4 SUMMARY OF THE RESULTS

The first fundamental frequency of FM 106 through FM 111, as shown in Table 7.3, was summarized from plotted data of each test. This data is archived and available at NRL. The measured first fundamental frequency agreed closely with the expected frequency derived from analysis.

The pre-test and post-test frequency signatures for each axis were superimposed and plotted against each other. Minimal amplitude changes between the pre- and post-test signatures indicated that crystal shifting might have occurred within the structure. However, there were no significant frequency changes between these two signatures indicating that the structure of each CAL Module is sound and was not damaged during the test.

Following structural environmental testing, a comprehensive performance test of the AFEE and TEM electronics was performed. This test was successfully performed on CAL Modules FM 106 through FM 111 in accordance with LAT-PS-01513, *CAL Functional Test and Calibration Procedure*.

Table 7-3: First Fundamental Frequency of FM 106 through FM 111

FIRST FUNDAMENTAL FREQUENCY (Hz)			
Accelerometer ID 01 (+Z Structure, Center)			
CAL MODULE	X	Y	Z
FM 106	170	183	205
FM 107	178	175	200
FM 108	165	175	198
FM 109	163	165	200
FM 110	170	168	198
FM 111	160	170	199
Accelerometer ID 02 (-Z TEM Power Supply, Center)			
CAL MODULE	X	Y	Z
FM 106	260	250	205
FM 107	260	255	200
FM 108	260	260	198
FM 109	243	255	200
FM 110	265	265	198
FM 111	265	260	199

8 CONCLUSIONS

CAL Modules FM 106 through FM 111 passed the acceptance structural environment test program since the following criteria, as specified in LAT-PS-04454, *CAL Flight Module Vibration Test Procedure*, were met:

- The acceptance test levels were applied in accordance with the test levels and limits specified in Table 6.1, Figure 6.1 through Figure 6.4.
- The GLAST CAL Module did not incur damage.
  - Pre- and Post- Frequency Response Functions indicated no significant changes in dynamic response (less than 10% frequency shift).
  - Visual inspections showed no physical damage.
- Acquisition of data was recorded in accordance with Section 5.2.
- Successful Comprehensive Performance Test of the AFEE and TEM electronics, in accordance with LAT-PS-01513, *CAL Functional Test and Calibration Procedure*, following completion of applied test levels.
- Successful cosmic muon tests, in accordance with LAT-PS-01513, *CAL Functional Test and Calibration Procedure*, following completion of the Comprehensive Performance Test.